Lightning Protection, Grounding and PoE

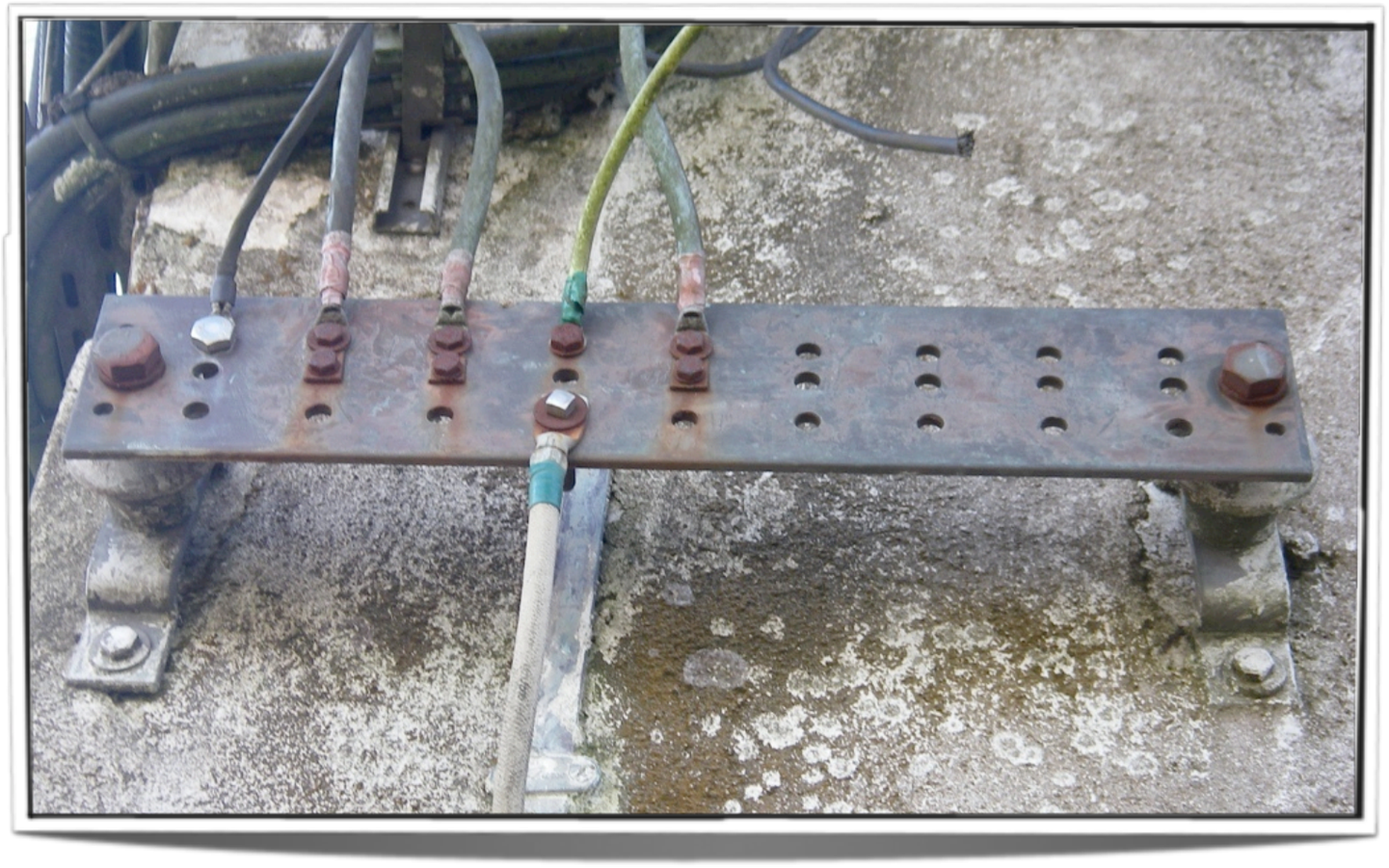
Training materials for wireless trainers

The Abdus Salam
International Centre
for Theoretical Physics

Grounding & Bonding

Why use proper grounding?

- Protect equipment from high voltages caused by lightning and power faults
- Protect personnel from dangerous conditions
- Dissipate electrostatic charges
- Provide a zero volt reference
- Reduce noise and interference



Definition of ground

Ground: A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth.

--John Cadick, Electrical Safety Handbook

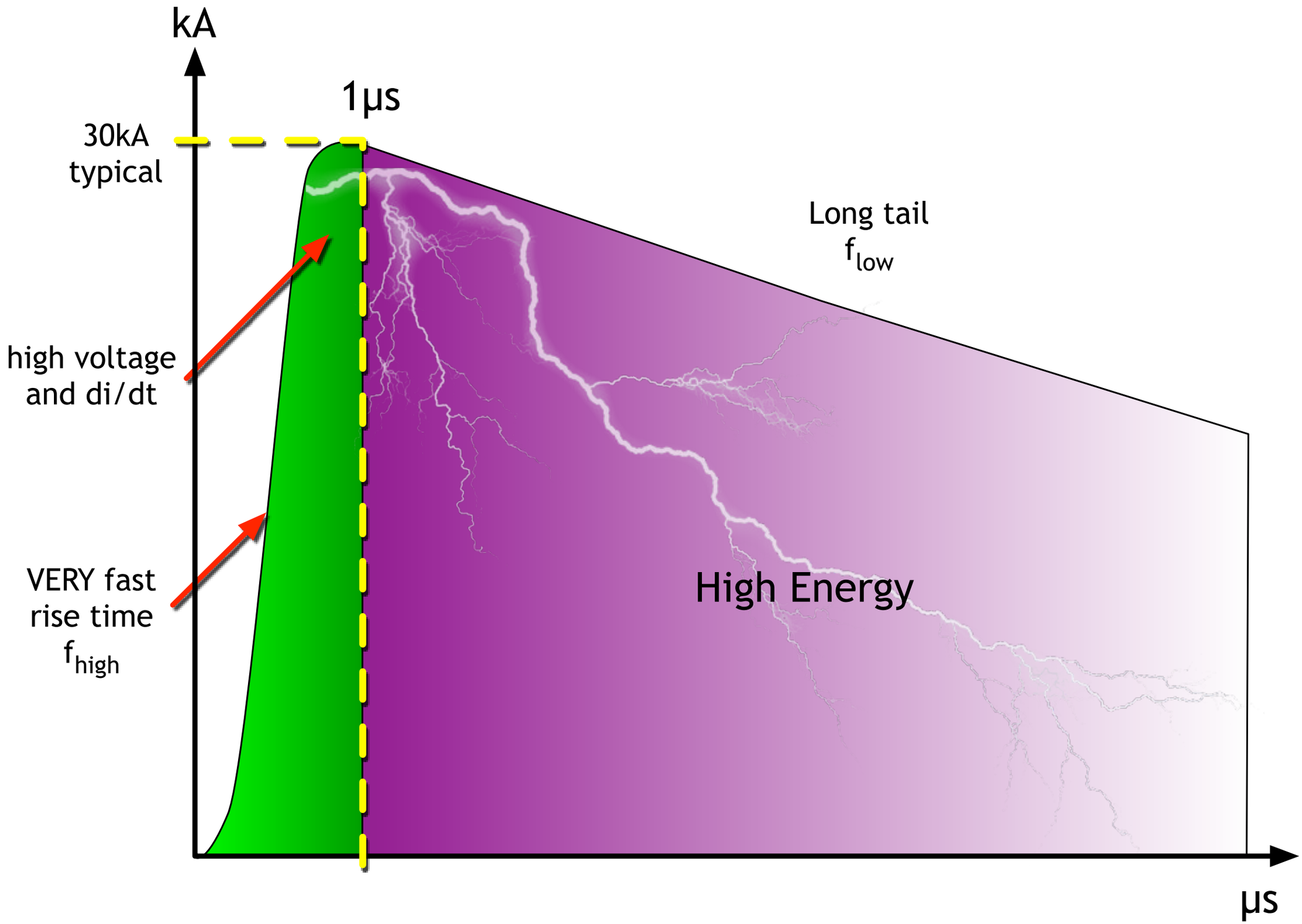
Electrostatic damage

- Caused when current passes from one object to another.
- Usually high voltage, but low current.
- A typical 1 cm electrostatic arc from a finger to a doorknob is around 19,000 Volts!
- Although damage is not usually visible with electrostatic discharge, it is the leading cause of electronic equipment failure.
- Humidity and temperature can help control electrostatic energy, but physical protection must also be deployed to prevent damage.

Lightning characteristics

Instantaneous power	> 1 Megawatt
Total energy	> 250 Kilojoules
Sound pressure	90 atmospheres at 500m away
Temperature	30 000+ K (5 times surface of the sun)
Rise time	0.1 to 5 microseconds
Average current	30 kA
Peak power	one Terawatt for ~30 μs
Duration	300 μs + repeats
Channel length	5 km+

Lightning impulse characteristics



Grounding system components

The two areas of grounding that pertain to telecommunications equipment are:

- Equipment grounding system (safety ground)
- Grounding electrode system (earthing system)

What should be grounded?

If it is made of metal, it should be grounded.

- Electrical boxes
- Electrical conduits
- Equipment cases and doors
- Antennas
- Lightning arrestors
- Towers
- Guy wires

Electrical power faults

Types of electrical system faults:

- Phase-to-phase faults
- Phase-to-neutral faults
- Phase-to-ground: more than 90% of electrical system faults will be phase-to-ground faults
- A phase-to-phase or phase-to-neutral fault will almost always trip the overcurrent device (circuit breaker or fuse)
- But...

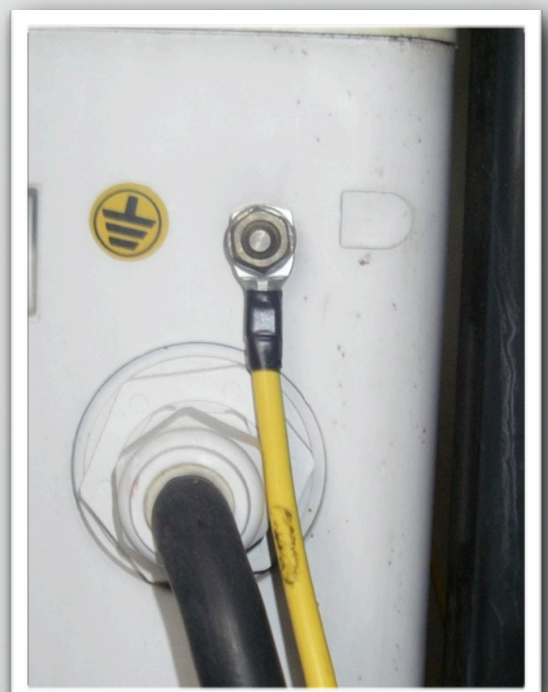
Electrical power faults

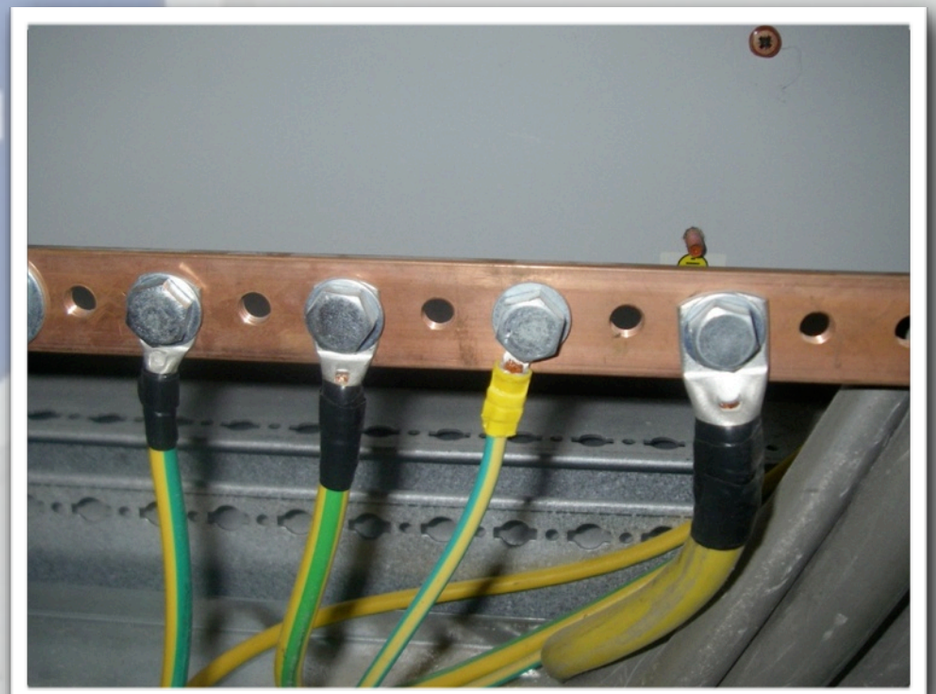
A phase-to-ground fault will ***not*** trip the overcurrent device if the impedance of the equipment grounding system is too high.

The following factors govern equipment grounding conductor impedance:

- Tightness of connections
- Length of wire
- Proximity to circuit conductors during fault conditions
- Number of bends and bend radius

Grounding electrical boxes





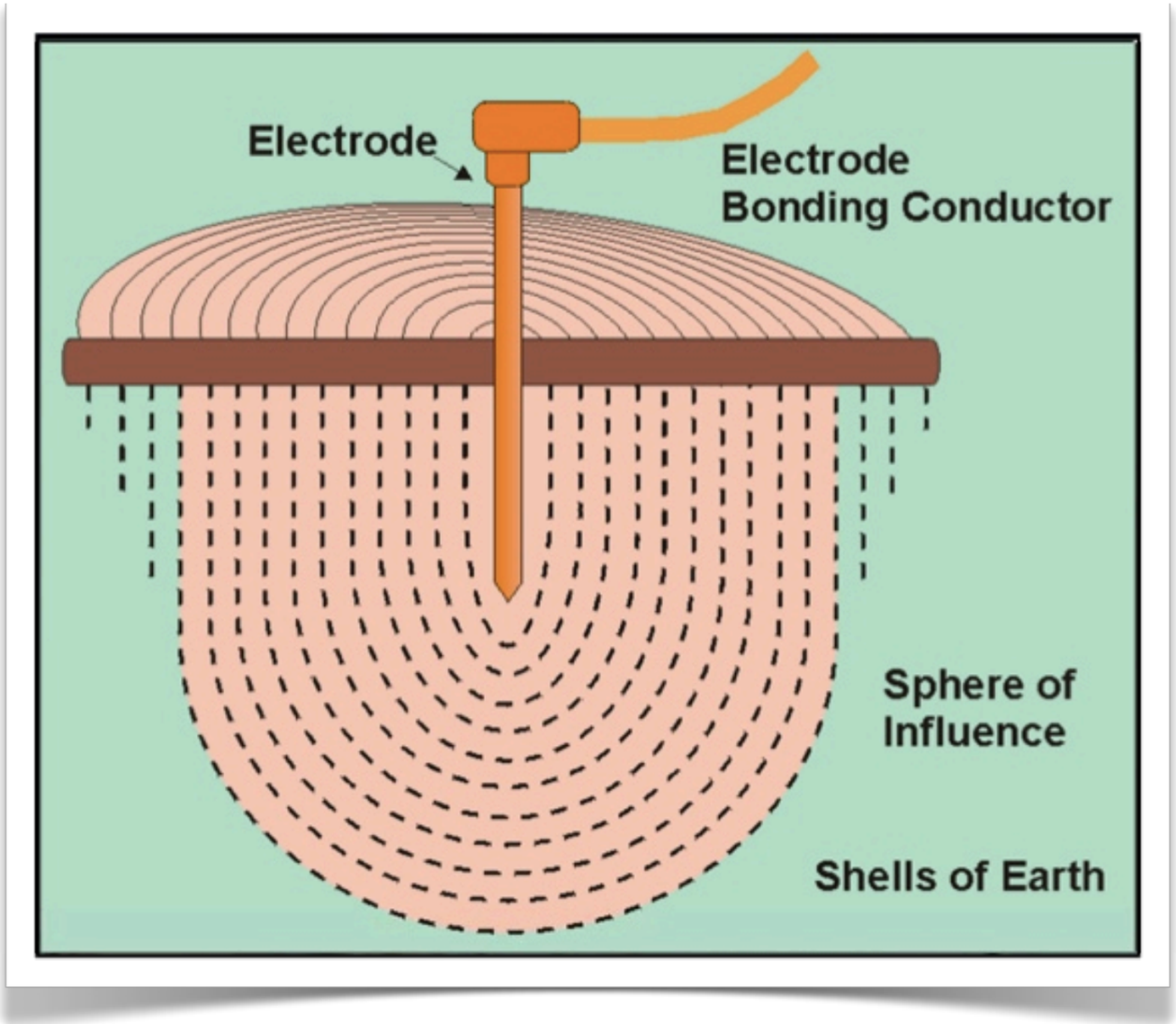
Tower grounding

Tower grounding

Grounding system components

The grounding electrode system consists of:

- Grounding field (earth)
- Grounding electrode
- Electrode bonding conductor



Grounding electrode system

Grounding electrode:

- Metallic conductor (e.g., rod 17 mm in diameter), pipe (19 mm diameter) at least 2.4 m long, plate or ring (or other metallic object) in contact with the earth used to establish a low resistance current path to earth.

Grounding Electrode System:

- Network of electrically connected ground electrodes used to achieve an improved low resistance to earth.

Conductor surface area

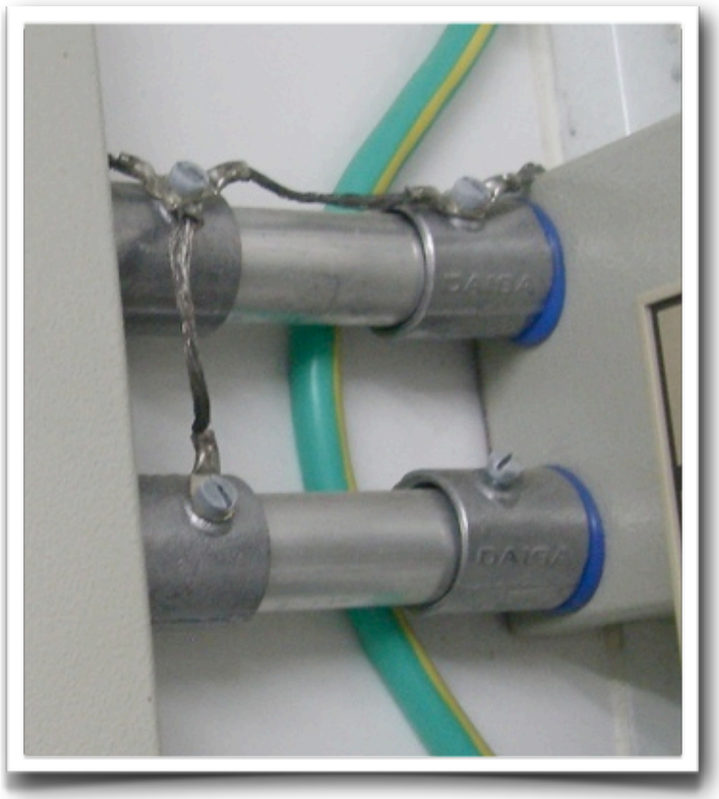
The most effective material for a ground system is ***copper strap***. Copper is a good electrical conductor, is only moderately attacked by ground and air borne acids, and should have a life-span measured in years.

Since lightning has a large portion of its energy in the RF range, it will behave like an RF signal. That means the energy will only be conducted on the skin of the conductor (***skin effect***). Such currents following a round conductor will not make extensive use of its large cross sectional area. With a 1-1/2 inch (38 mm) or larger flat strap of at least 26 gauge (0.41 mm), both surfaces will conduct the surge.

Definition of bonding

Bonding: The permanent joining of metallic parts to form an electrically conductive path that will ensure electrical continuity and the capacity to conduct safely any current likely to be imposed.

--John Cadick, Electrical Safety Handbook



Electrolytic potential

When two different metals are in moist contact their electrolytic potential should be as close as possible to minimize ***electrolytic corrosion***.

Dissimilar metals produce an electrical potential difference, which will corrode the metal material.

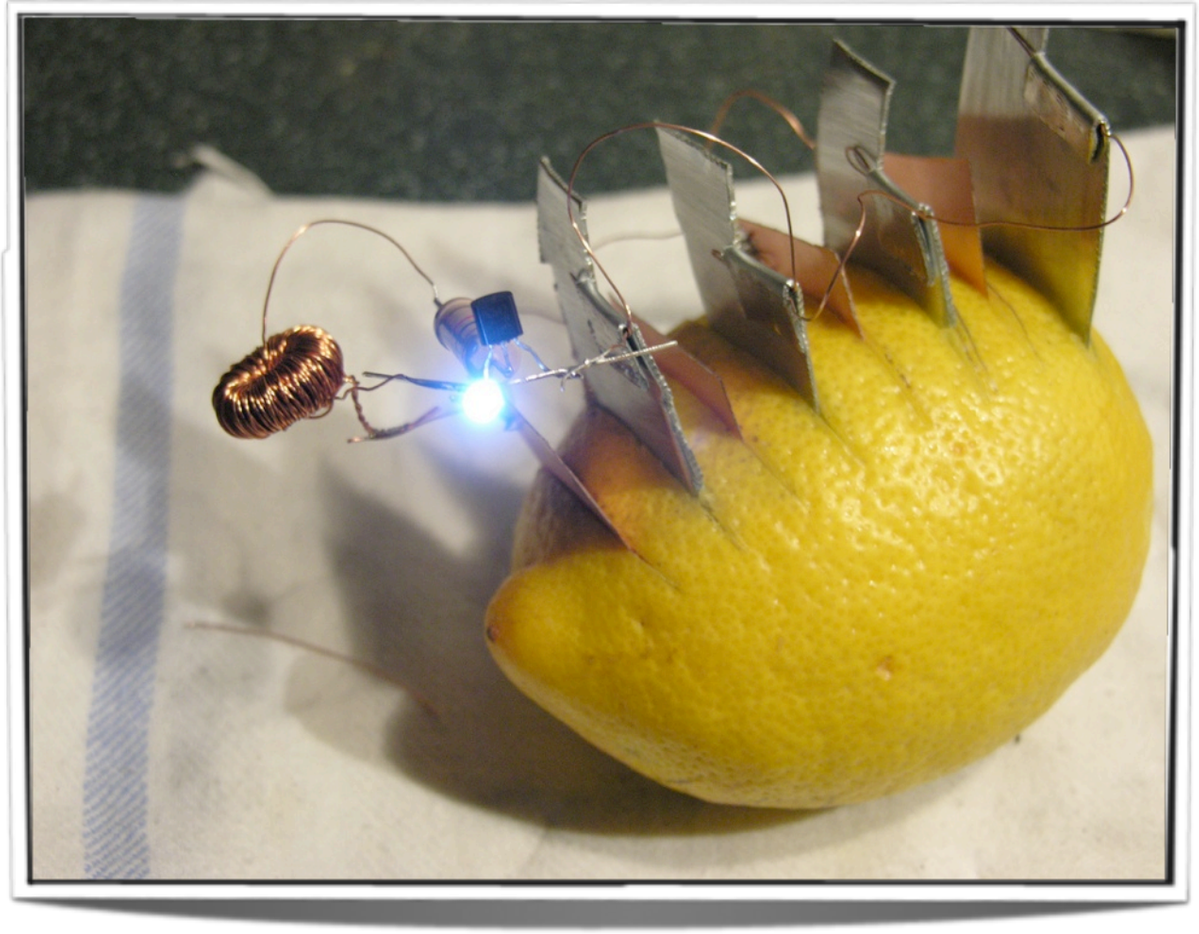


Photo by Flickr user s8

Metal corrosion

Copper should never touch galvanized material directly without proper joint protection. Water shedding from the copper contains ions that will wash away the galvanized (zinc) tower covering.

Dissimilar metals

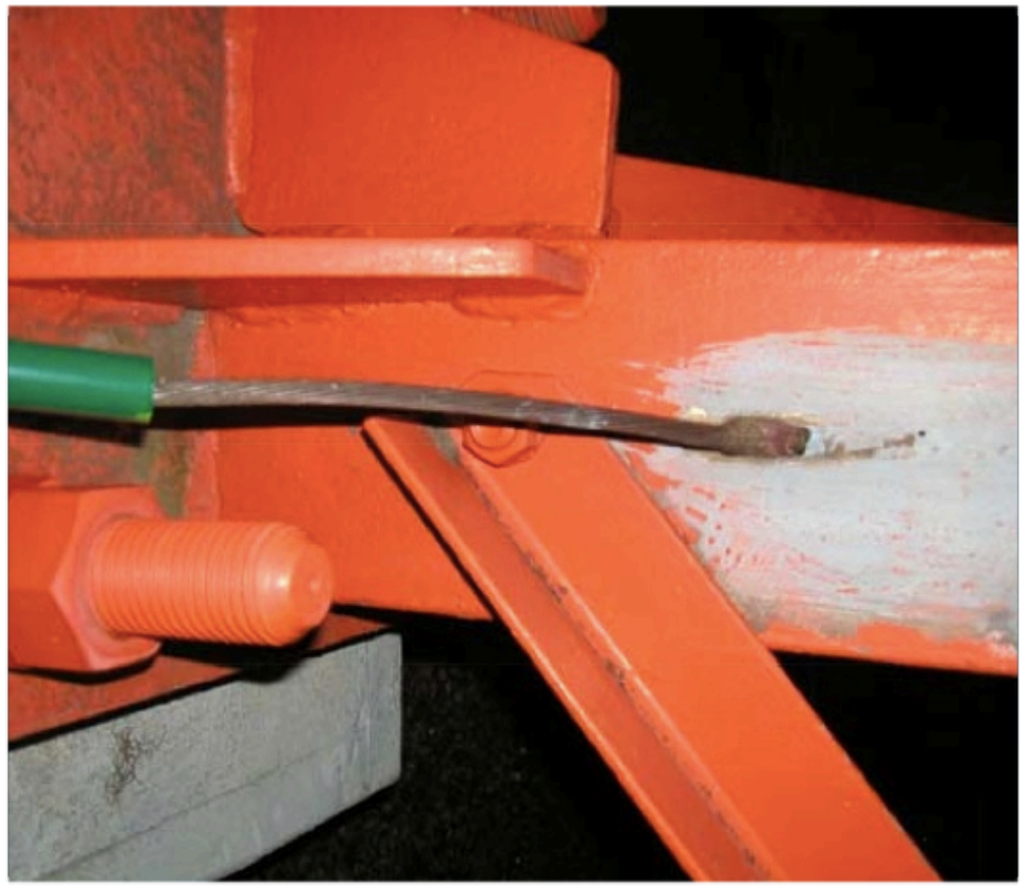
In the presence of oxygen, the zinc of galvanized steel sacrifices itself before the steel corrodes, since zinc is more negative than iron.

Stainless steel can be used as a buffer material. However, be aware that stainless steel is not a very good conductor. If it is used as a buffer between copper and galvanized metals, the surface area of the contact should be large and the stainless steel should be thin.

Joint compound should also be used to cover the connection so water can not bridge between the dissimilar metals.

Electrolytic potential

Metal	Potential (V)
Aluminum	+1.67
Zinc	+0.76
Chromium	+0.71
Iron	+0.44
Cadmium	+0.40
Nickel	+0.25
Tin	+0.14
Lead	-0.13
Copper	-0.34
Silver	-0.80
Gold	-1.86



From: Physical Design of Yagi Antennas. David Leeson, American Radio Relay League, ARRL, 1992

Electrodes

Electrodes specifically designed and installed for grounding:

- Buried ground rods
- Buried ground rings
- Buried metal plates
- Concrete encased electrodes
- Chemical ground rods

Ground rods

Grounding rods (or ***radials***) are the most cost effective grounding technique considering system impedance, material cost, and installation labor.

Radials do have a limit on their effective length. If the surge energy has not been launched into the soil within the first 22 cm, the inductance of the radial will prevent any further effective prorogation. Therefore, as a general rule of thumb, all radials should be ***at least 15 cm long*** and ***no longer than 23 cm***.

Installing a grounding ring

A grounding ring consists of non-insulated conductors buried in the shape of a ring.

- Buried a minimum depth of 80 cm
- Minimum size 2 AWG (7.91 mm) and 6 m in length

Installing a grounding ring

Using cold water pipes

- Historically the first choice for ground
- Provides low resistance to earth
- Must be electrically continuous: no plastic pipes or couplers. Any discontinuities can be bonded across.
- Should be used to lower the system resistance to ground.
- Must **not** be used as the only ground source, but only in conjunction with a primary electrode.

Using cold water pipes

Advantages:

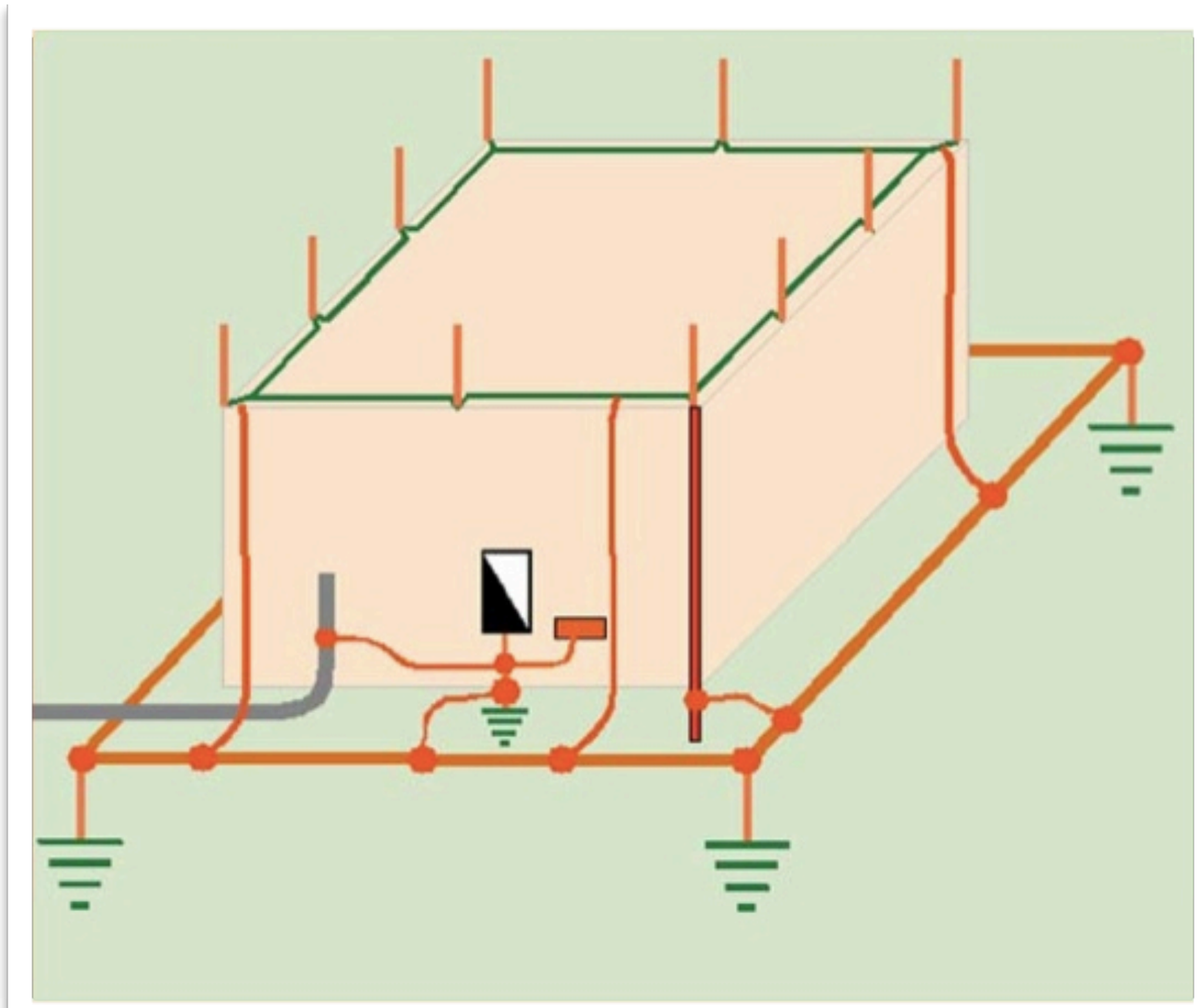
- Most homes have water
- Easily accessible
- Usually less than 3Ω resistance to earth

Using cold water pipes

Disadvantages:

- Bonding causes electrolysis of the installed metallic pipes, reducing expected life span
- Many cities use PVC
- Many cities are installing isolation joints made of PVC to separate their systems
- Future repairs may be plastic

Safety: all systems bonded



Earth resistance

Generally speaking, "earth resistance" is the resistance of soil to the passage of electrical current.

The earth is a relatively poor conductor of electricity compared to normal conductors like copper wire. But if the path for current is large enough, the resistance can be quite low and earth can be a good conductor.

Soil resistance

These factors can affect the resistance of soil:

- Moisture content of the soil
- Quantity of electrolytes
- Type of electrolytes
- Adjacent conductors
- Temperature
- Electrode depth
- Electrode diameter
- Electrode spacing distance

Soil doping

The earth is a conductor because of the number of ionic salts present in the soil. Conductivity can be improved by adding more ions to the soil.

Soil doping can be done by either adding water or a saline solution to the soil around the grounding system. If the soil already has a sufficient amount of naturally occurring salts, adding water will free the ions and improve conductivity.

If few natural ions are available, Epsom salts can be added to the soil to increase the conductivity.

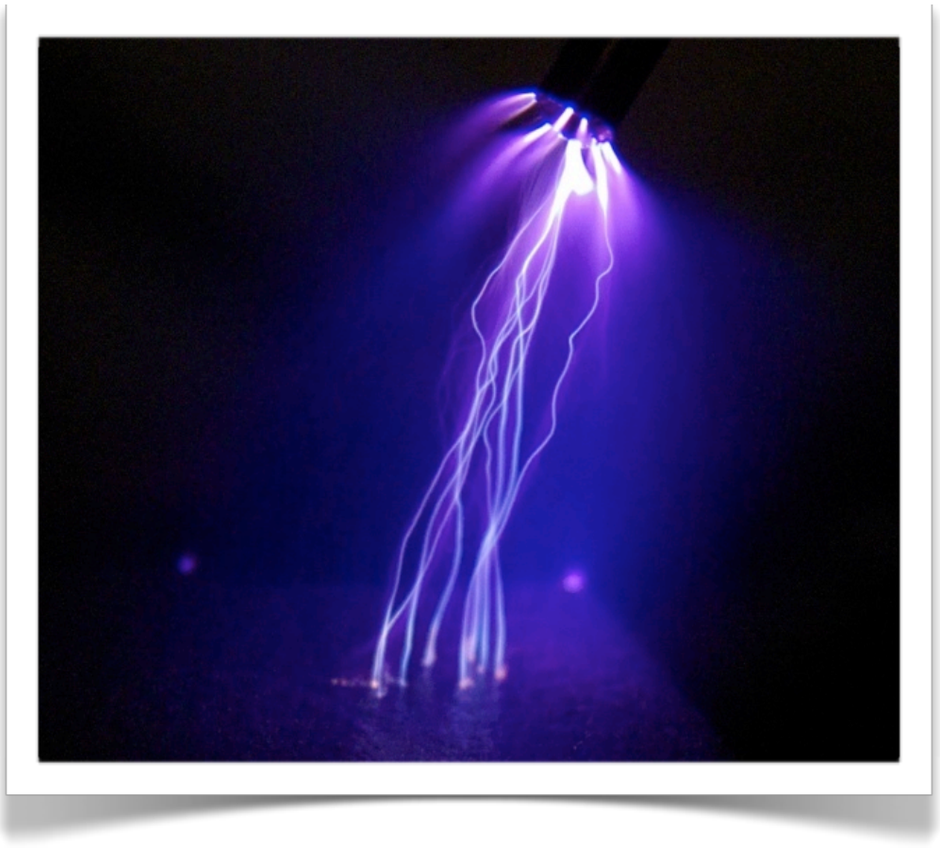
Depending on the amount of rainfall, doping the ground system radials with 10 kg of salt per per rod may last approximately two years.

Coils and pigtails

Coils and pigtails introduce an inductance to the ground path. Inductance resists changes in current.

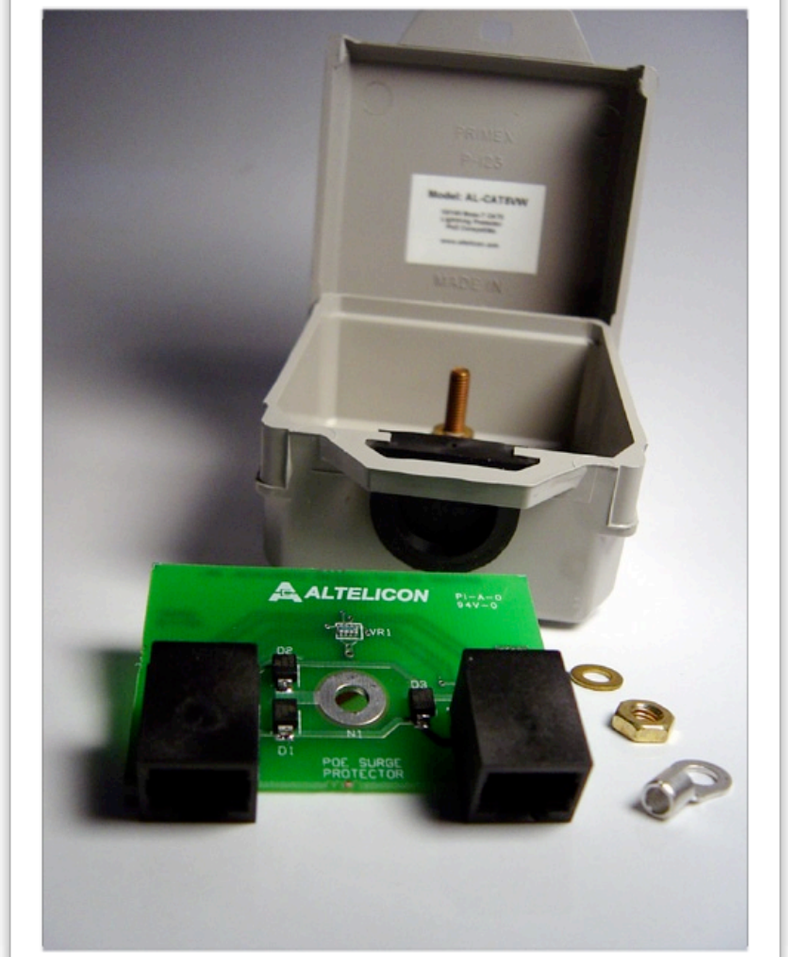
If there is too much inductance in your ground line, then a surge might find it easier to go through the equipment rather than the now restrictive ground path.

Avoid sharp bends in ground conductors. Corona effect at the bends will cause the wire to heat and melt.



Lightning arrestors

- Coaxial lightning arrestors will shunt high voltages on an antenna line to ground.
- UTP lightning arrestors will protect Ethernet lines from power surges.
- Properly grounded surge protectors (power strips) can help protect AC equipment.

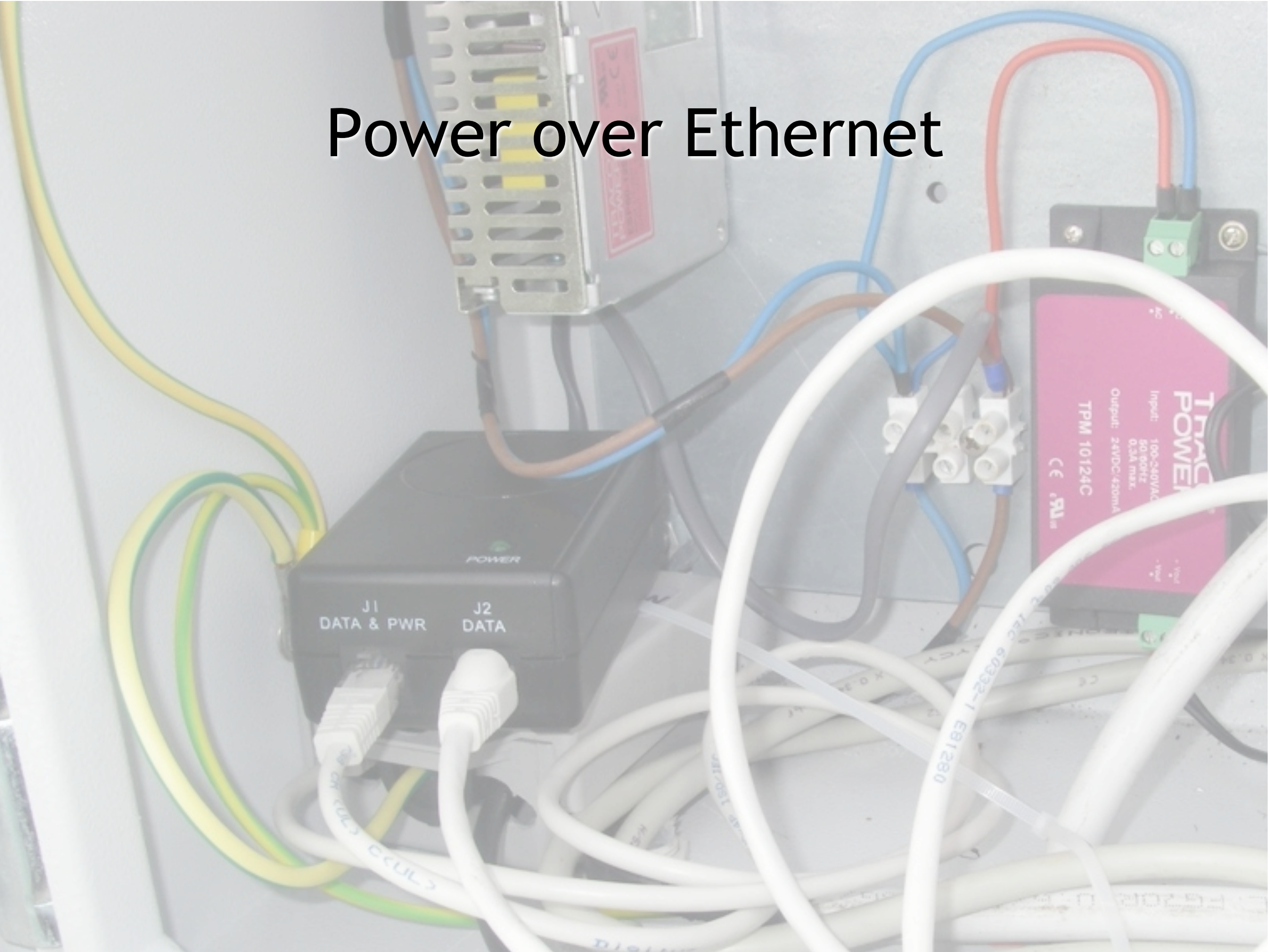


Lightning rods

A ***lightning rod*** is a conductor installed at the top of a tower or tall building, intended to attract lightning away from sensitive equipment and divert the strike directly to ground.

Photo of Eiffel Tower lightning rod
by Flickr user elbragon

Power over Ethernet



Why Power over Ethernet (PoE)?

- Saves money and installation time
- More flexibility in the placing of devices
- Quite useful for outdoor installs, allowing for a long distance between the AP and the computer
- Does not require an electrician to install

PoE issues

- Standard or not?
- End Span or Mid Span?
- Requires Cat5e or Cat6 with less than 25 Ω loop
- Pin assignment type A or B?
- Measured resistance for 10 meters = 0.8 Ω
- Should use outdoor rated UTP cable
- Some equipment requires “good power” signature

IEEE standard 802.3af-2003

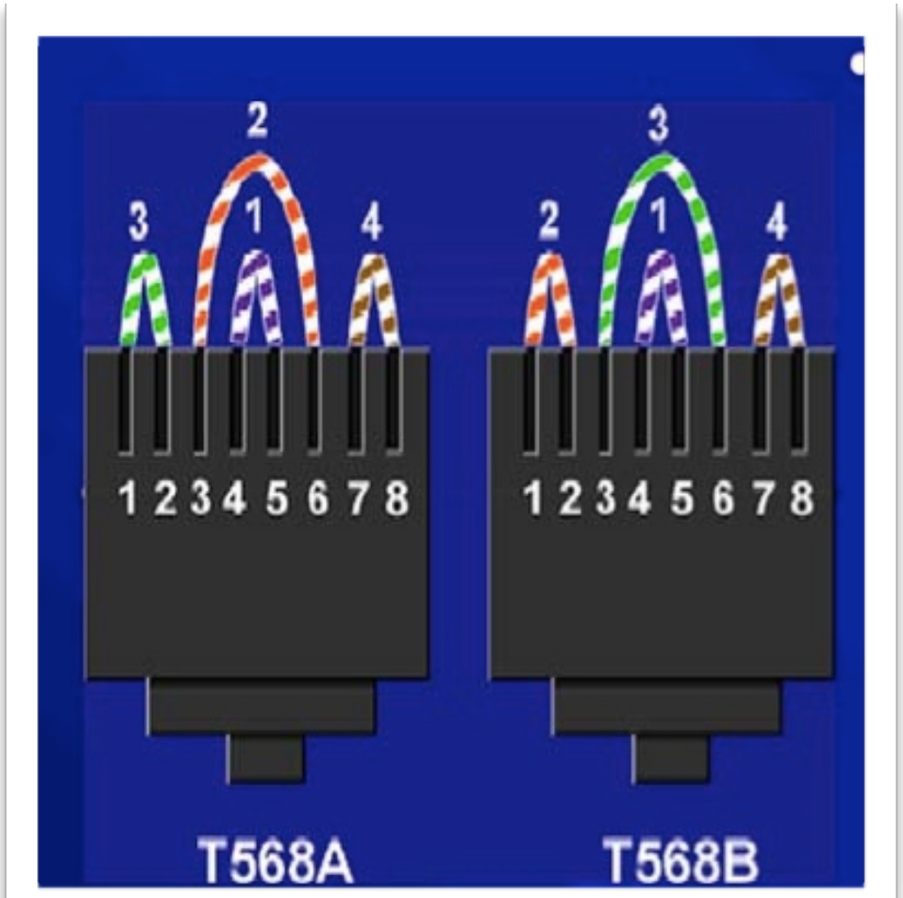
- Powering Ethernet devices through data cables
- Standard Title: Data Terminal Equipment (DTE) Power via Media Dependent Interface (MDI)
- Approved June 2003
- Supports up to ~13W on a single cable

IEEE standard 802.3at-2009

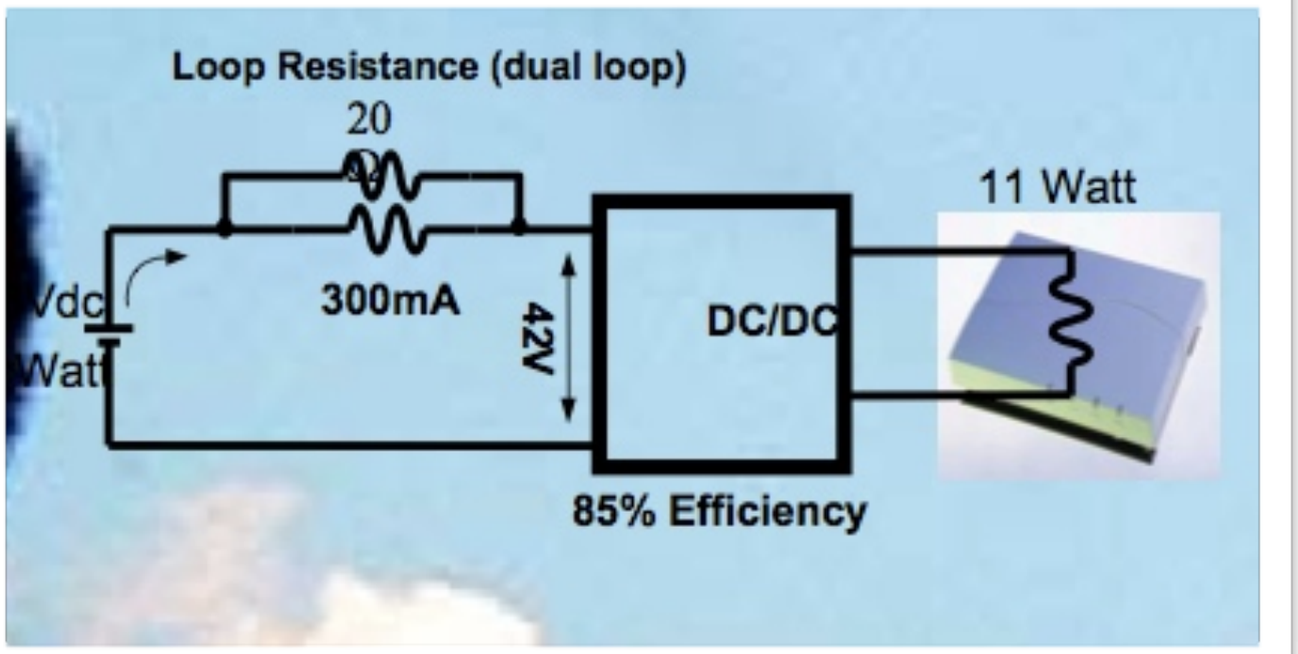
- Extension to 802.3af-2003
- Approved September 2009
- Supports up to 25W per cable
- Proprietary extensions can support up to 51W!

End span or mid span

- PoE (802.3af) runs at 48VDC, with a max current of 350mA, capable of feeding a maximum load of 12.95W accounting for the cable losses
- End span 802.3af provides power on either the data pairs (1,2;3,6) or spare pairs (4,5;7,8)
- Mid span 802.3af provides power on the spare pairs (4,5;7,8).



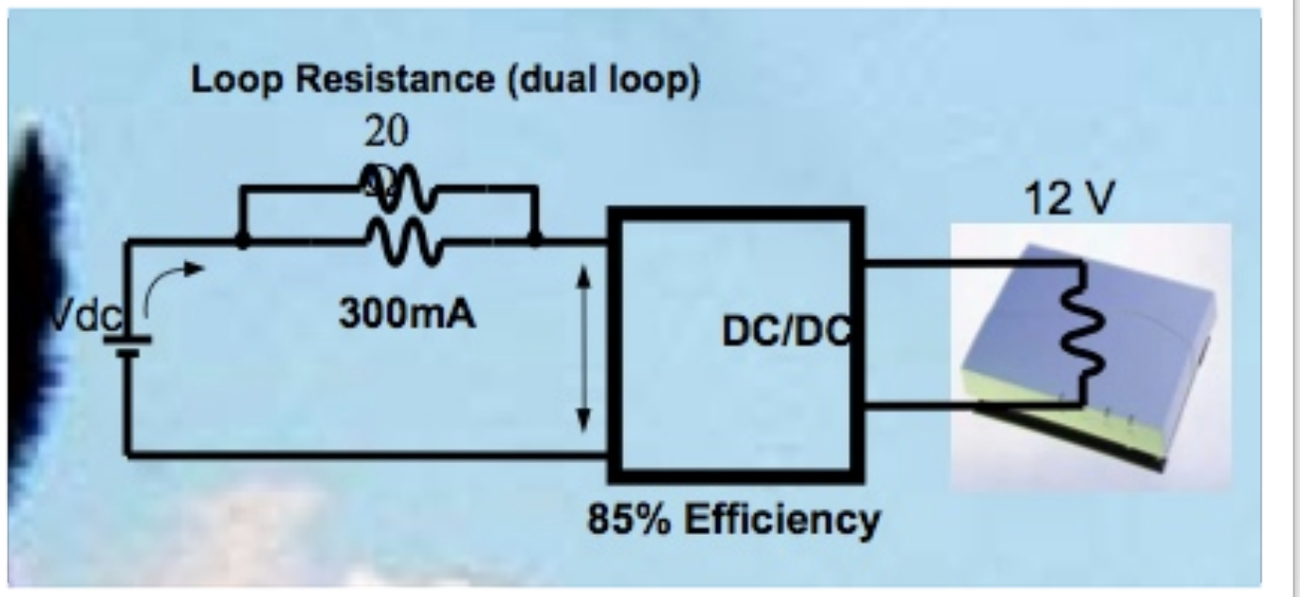
Power delivered via PoE



Assuming:

- 48 VDC feed
- 300 mA continuous
- Maximum 20 Ω loop resistance
- Delivering power over CAT 5 Spare Pairs (pins 4+5 & 7+8)

Voltage drop over PoE



Assuming:

- 15 VDC feed
- 12 VDC powered AP
- The DC/DC converter can be simple voltage regulator IC
- This will allow for voltage loss on the cable.
- Similar considerations for a 5 V load

Powered device detection signature

- Power Source Equipment (PSE) applies test voltages to determine the load characteristic of the Powered Device (PD).
- The load characteristics of the PD are called the ***PD detection signature***.
- The PSE reads the PD detection signature to determine whether to supply power and how much power to supply.
- The detection signature enables the PSE to provide the right level of power, providing a form of power regulation.
- This handshake is only implemented in high end switches.

Conclusions

- Proper grounding is critical to avoid damage from electrostatic charges and lightning.
- Improper wiring can damage equipment and endanger lives.
- Ground protection is an active system that requires engineering and maintenance.
- To maximize grounding system life, avoid direct contact between dissimilar metals.
- Power over Ethernet is an inexpensive and useful solution for providing power to wireless devices.

Thank you for your attention

For more details about the topics presented in this lecture, please see the book ***Wireless Networking in the Developing World***, available as free download in many languages at:

http://wndw.net